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GB 2084315 A

(58) Field of Search
UK CL (Edition O) **G1A ACEX**
INT CL^6 **G01B 9/00 9/02**

(54) **Laser interferometer with linear array of photodetector elements**

(57) A laser interferometer for calibrating displacement has a linear array of elongate parallel photosensitive elements (70) situated in a spatial fringe field created from interfering beams having non-parallel directions of propagation. The elements are grouped into sets in an interleaved repeating pattern. Movement of a retroreflector (48) causes a detectable shift in the fringe field. The apparatus includes a beam splitter (44) creating a pair of orthogonally polarised beams. One of the beams is diverted into relatively fixed retroreflector (46), the other passes undiverted into retroreflector (48). The beams recombined at beam splitter (44) are partly overlapping and parallel. A birefringent prism (60) refracts the beams through different angles causing them to converge and polarising element (62) mixes their polarisation states so they interfere and generate a spatial fringe field. The apparatus may also calibrate angular displacement, straightness, squareness, pitch roll or yaw on a machine tool.

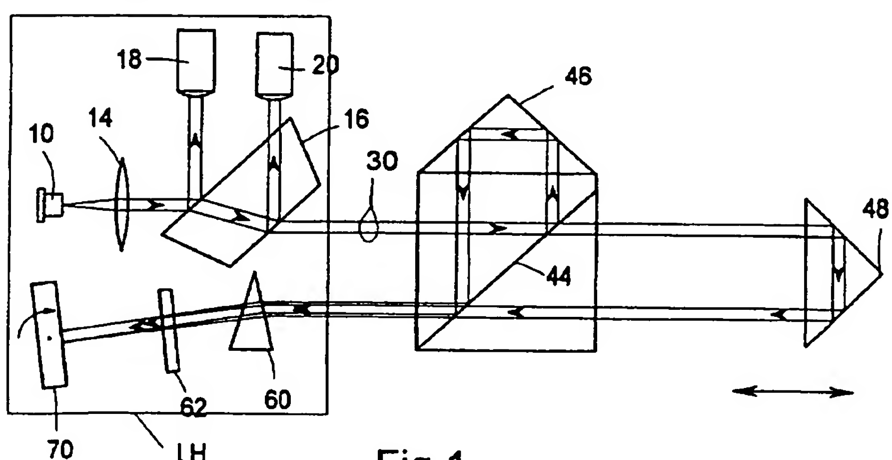

Fig.1

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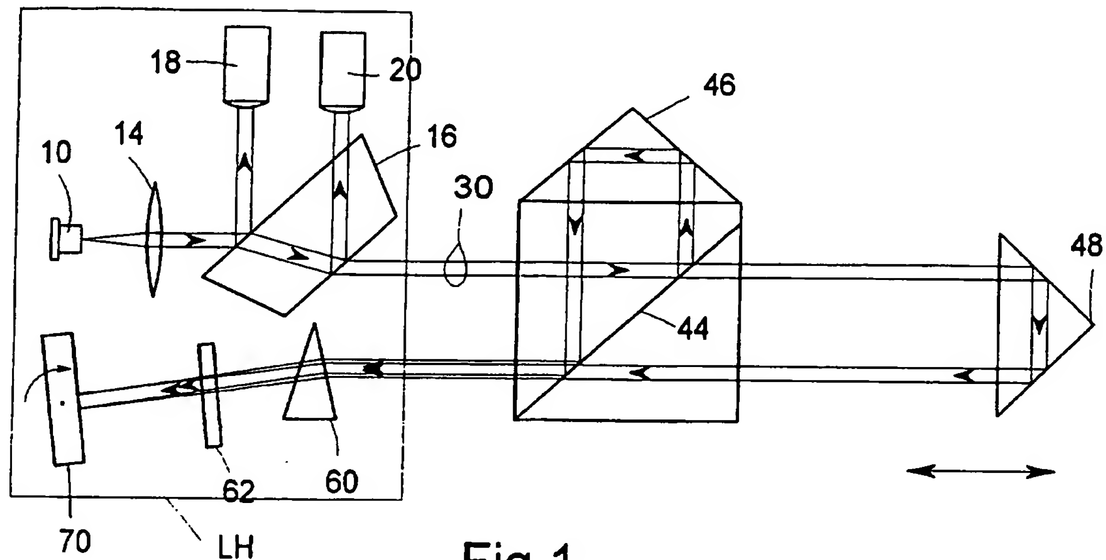

Fig.1

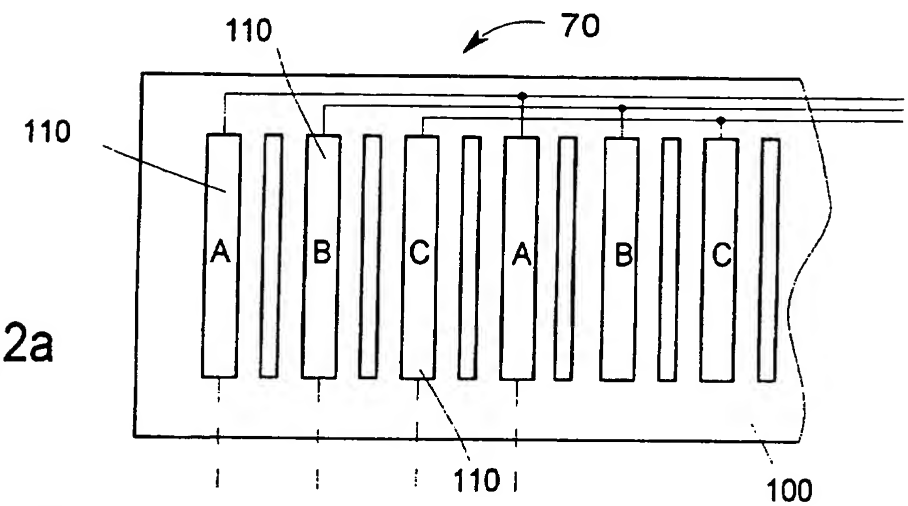

Fig.2a

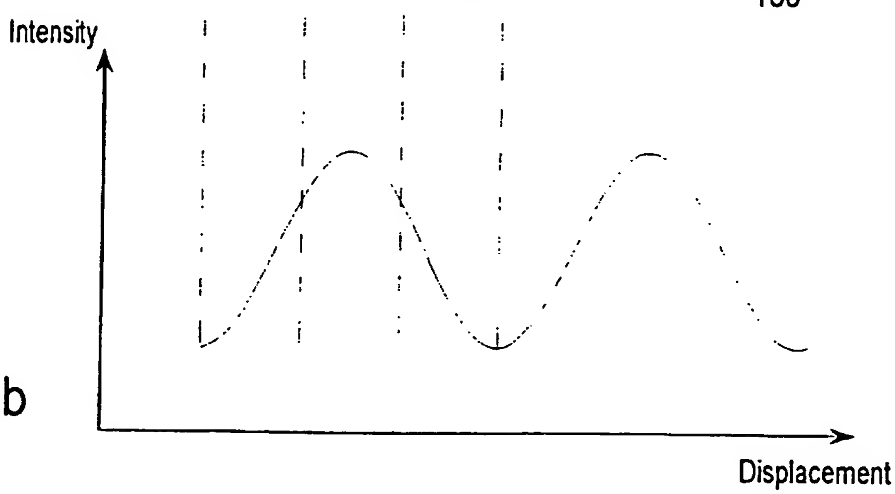

Fig.2b

INTERFEROMETER

The present invention relates to an interferometer which may be used, for example, to calibrate linear or angular displacement, and straightness, squareness, pitch roll or yaw on a coordinate positioning machine such as a machine tool.

The use of, for example, laser interferometers for this purpose is well known per se. Such prior art interferometers typically comprise a laser and detector unit contained within a single housing, a reference arm provided by an interferometer optic and retroreflector maintained in a fixed spatial relationship relative to the interferometer optic, and a measuring arm including a retroreflector mounted to the object whose displacement is to be determined. Reflected beams from the reference and measurement arms are combined at the interferometer optic to generate interference.

The present invention relates to a laser interferometer generating interference wherein the interference takes the form of a spatial fringe field; i.e. in the form of a series of fringes extending in a direction transverse to the combined beams.

In one embodiment the beams in the reference and measuring arms have different polarisations, and are deflected into convergence by an optical element such as a prism. Preferably, prior to entering the prism the beams will propagate in substantially parallel directions, offset from each other coaxially, yet overlapping to an extent; in this case, the prism is of birefringent material (this configuration simplifies the setup of the apparatus).

In an alternative embodiment the optical elements such as retroreflecting elements of the reference or measuring

arms, or the beam splitter, are configured to provide convergence of the interfering beams.

An embodiment of the present invention will now be described, by way of example, and with reference to the accompanying drawings wherein:

Fig 1 is a schematic representation of a laser interferometer according to the present invention; and

Figs 2a and 2b show a detail of the detector provided in the interferometer of Fig 1, and the distribution of interference fringes relative thereto.

Referring now to Fig 1, a laser in the form of a diode 10 emits a beam 12 of laser light, which is collimated by a lens 14. The beam 12 subsequently passes through a prism 16 which deflects part of the beam 12 into temperature and frequency stabilisation channels 18,20 for the laser diode 10. The output beam 30 of the frequency stabilised unit is incident upon a polarising cubic beam splitter 44, which splits the beam 30 into two linearly orthogonally polarised beams 40,42 propagating in orthogonal directions. The beam 40 is directed into a reference optical path provided by a retroreflector 46, whose position is fixed relative to the polarising cubic beam splitter 44. Beam 42 continues undiverted into a measuring optical path in the form of a retroreflector 48, fixedly connected to an object whose displacement is to be determined. Beams 40 and 42 are reflected parallel to their incident path by retroreflectors 46 and 48; beam 40 is additionally reflected by beam splitter 44 in a return direction toward the laser head LH.

However, the geometry of beam splitter cube 44 and retroreflector 46 are such that the beams 40 and 42 are no longer coaxial but may partially overlap when reflected towards the laser head LH, but nonetheless remain parallel.

Upon entering the laser head LH, the beams 40,42 pass through a birefringent element, provided in this example by a "calcite" wedge prism 60, which refracts the beams 40,42 through an angle which is dependent upon their polarisation state, and thereby has the effect of converging the beams. a 45° polaroid 64 is subsequently provided in the path of the convergent beams to mix their polarisation states, thereby enabling interference between the beams 40,42 for the first time.

Because the beams 40,42 are interfering as a result of their mutual convergence, rather than co-axial superposition (as is usual with a laser interferometer) a spatial fringe field will be generated in a plane transverse to the direction of travel of the beams 40,42. The periodicity of the fringe field will be determined by the convergence angle of the two interfering beams. To detect the fringe field, and the resultant lateral shift upon linear movement of retroreflector 48, an electrograting photodetector 70 is provided.

Referring now to Figs 2a and 2b, the electrograting photodetector 70 consists of a semiconductor substrate 100, upon which a plurality of elongate, substantially parallel photosensitive elements 110 are provided, (suitably interspersed by guard diodes 112). The elements 110 are divided into a plurality of sets, the number of sets being determined by the number of phase-shifted signals required from transverse displacement of the spatial fringe field upon linear movement of retroreflector 48. In the present example, sensitive elements 110 are divided into three sets, denoted 110A,110B,110C. Elements of a given set are connected in common, and the elements are provided on the substrate in a repeating pattern A B C. Referring now to Fig 2b, the intensity of the interfering beams upon the surface of the photodetector with transverse displacement across the surface of the photodetector is illustrated. It can be seen that the spacing of elements of a given set is

such that as the fringe field illustrated in Fig 2b moves across the surface of electrograting 70, the intensity of light incident upon elements 110A of the set a will be substantially the same; similarly, this is also the case for elements 110B, and 110C. The combined outputs of elements 110A,110B,110C respectively thus generate three substantially sinusoidal outputs, having phase shifts of 120°. These outputs may be combined in a manner known per se to generate a pair of sinusoidally varying signals having a phase shift of 90°, thereby enabling interpolation and determination of the direction of travel of retroreflector 48.

The pitch of the electrograting 70 (i.e. spacing between like elements 110A e.g.) can be altered relative to the spatial fringe field by rotating the electrograting about axis R until the fringe field and electrograting effectively have the same pitch.

Electrograting photodetectors are known per se from our prior published European Patent Application EP 543513.

In an alternative embodiment the beam splitter is a non-polarising beam splitter, and the apparatus is configured without the birefringent element or mixing polaroid. In this alternative example the beams may interfere at an angle by virtue of the construction and geometry of e.g. one of the retroreflectors or the beam splitter. Preferably in this example the beams will remain overlapped as illustrated in Fig 1 for ease of setup. This embodiment has the advantage of cheaper optics, but suffers from much larger light losses.

Although the present application describes a linear interferometer, the present invention is equally applicable to angular, straightness and other interferometry. For example in the case of angular interferometry the apparatus may not require a fixed length reference arm. Further,

elements other than the retroreflectors may be mounted to the object whose displacement is to be measured in order to generate the requisite relative change in path length. The illustrated embodiments employ corner cube retroreflectors, however any other suitable retroreflector may be employed. Other lasers, or light sources having appropriate coherence may be used, such as HeNe or Titanium Sapphire lasers, for example.

CLAIMS

1. An interferometer apparatus for measuring displacement of an object comprising:

a light source which emits a beam of substantially coherent light;

a first optical path, provided between a beam splitter and a first retroreflecting optical element;

a second optical path provided between the beam splitter and a second retroreflecting optical element;

light beams reflected from the first and second retroreflecting elements interfering to produce optical interference, and a change in displacement of said object causing a change in the relative optical path lengths of said first and second optical paths;

at least one photodetector in the path of the interfering beams;

characterised in that:

said interfering beams have non-parallel directions of propagation thereby to generate a periodic spatial fringe field; and

said photodetector comprises an array of elongate photosensitive elements situated in said fringe field, said elements being spaced apart in the direction of periodicity of the fringe field and in a direction transverse to their length, and being grouped into a plurality of sets with elements of a given set being electrically connected in common, the elements being interleaved in a repeating pattern, thereby to generate a plurality of cyclically varying phase-shifted electrical signals when movement of said object causes a change in the relative path lengths of the first and second optical paths and consequently a shift in the fringe field.

2. An interferometer according to claim 1, wherein said first optical path is a reference path having a fixed length and said second optical path is a measurement path,

said second retroreflecting optical element being connected to said object.

3. An interferometer apparatus according to claim 1 or claim 2 wherein said beam splitter is a polarising beam splitter, and wherein said reflected beams extend substantially parallel to each other, and are at least partially overlapping, the apparatus further comprising a birefringent element in the path of said beams to cause convergence or divergence of said beams, and a polarising element to mix the polarisation states of the reflected beams thereby to cause said interference.

4. An interferometer apparatus according to any one of the preceding claims wherein said array is rotatable about an axis extending parallel to the length of the elements, thereby to adjust the pitch between adjacent element of the same electrical set relative to the pitch of the incident spatial fringes.

5. An interferometer according to claim 1 wherein said light source is a laser.

6. An interferometer substantially as described herein and as illustrated in the accompanying drawings

The Patent Office

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Claims searched: 1

Examiner: Gareth Griffiths
Date of search: 22 February 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): G1A (ACEX)

Int Cl (Ed.6): G01B 9/00, 9/02

Other: Online Database: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB2084315 A (N.V.PHILLIPS) whole document	1, 2, 3, 5

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
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